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ABSTRACT

This researcher investigated the relationship of hierarchical classification processes in subjects categorized as to developmental level as defined by Piaget's theory, and explored the validity of the hierarchical model and test used in the study. A hierarchical classification test and a battery of four Piaget-type tasks were administered individually to a group of 60 randomly-selected high school students and to a group of 52 randomly-selected junior high school students. Students in each group were categorized as concrete, transitional, or formal by determining their performance on the battery of four Piaget-type tasks in science. In addition to the Piaget-type tasks, a hierarchical classification test was administered to each individual within each group. The test consisted of a six-level hierarchy called a Natural Things Test. Results supported the assumption that students capable of forming and manipulating symbolic representations of experience (Formal Operations) would experience little difficulty on the hierarchical test. The assumption that students dependent upon concrete cues would experience difficulty on the hierarchical test was not as clearly supported. (Author/HM)

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A STUDY OF HIERARCHICAL CLASSIFICATION IN CONCRETE AND FORMAL THOUGHT

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INTRODUCTION

Abstract learning and reasoning ability in humans has increasingly become the focus of research in science education. Much of this work has been based on the work of Piaget and his co-workers [1,2,3,]. Piaget, in dealing with the concept of abstract learning, posits two distinct forms of abstraction in human cognition--simple and reflective. He defines these terms respectively as "abstractions from the objects themselves" and "the transposition from one hierarchical level to another level", [4]. Yet, while this definition provides broad and general guidelines for his theory of intellectual development, it does not provide the necessary operational structure for a feasible refined analysis of the concept of abstraction as it appears in human learning. In general, the literature frequently shows "a lack of awareness in diagnosing the term and a lack of knowledge as to how and when to elicit the process" [5].

In an earlier study, a systematic theoretical framework for human abstract cognition, accountable to the variety and scope of research subsumed by the concept of abstraction, was presented [6]. In that study, a hierarchical model of abstraction and a test based on one dimension of the model--hierarchical classification--was constructed and empirically evaluated using normal and mentally retarded subjects. The results supported the model and have been reported elsewhere.[7].

The purpose of this study was to further explore the validity of the model of abstract learning as an indicator of cognitive ability. Two central concerns were examined--(1) to explore the relationship between

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subject performance on hierarchical classification test and their developmental level as assessed by Piagetian tasks, and (2) to gain further information concerning the validity of the hierarchical model of abstraction used in the study.

THEORY

The concept of abstraction as used in this study is considered to be a cognitive process of discriminating specific attributes from the environment that can be combined to form generalized representations of experience [6]. These representations can take the form of classes, sets of relations, or operations. The ability to form classes is considered to be fundamental and basic to representations consisting of sets of relations and operations. These three modes of abstraction, (1) classification, (2) relations, and (3) operations, are referred to as Orders of Abstraction—an Order of Abstraction being defined as a cognitive mode of representing experience [6].

This study was specifically concerned with the Classification Order and the hierarchical test based on this Order. A general overview of the Order of Classification and the hierarchical test will be presented here since a detailed description of both have been reported elsewhere [6,7].

The Order of Classification is a hierarchy consisting of broad inclusive concepts at the top which subsume less inclusive concepts at lower levels. The lowest levels of this hierarchy are concerned with representations of immediate sensory data at the attribute level, while higher levels contain class categories or concepts built upon attributes assimilated in lower levels. The first six levels of this hierarchy are considered to be essential to the acquisition of higher levels of

abstraction.[1] Moreover, an individual incapable of performing successfully at the first three levels in this Order should not perform successfully at higher levels if the hierarchy is valid. This is due to the increase in generality and inclusiveness of the higher levels which require synthesis of more information for their attainment than do the subordiante categories.

Piaget's theory of cognitive development also suggests a hierarchy in which an individual increasingly becomes more proficient in forming and manipulating symbolic representations of experience. His empirical work with children gives evidence that cognitive development in an individual can be characterized by a series of stages: sensory-motor, pre-operational, concrete operational and formal operational. At each stage, the child's interaction with immediate experience can be characterized by the particular logical structures available to him. These stages, in general, reflect the child's diminishing dependence upon concrete sense stimuli as the ability to form and manipulate representations of experience increases—this latter ability becoming fully developed in formal operations and characterizing adult intelligence [8].

This suggests that since the model of classification used in this study is a hierarchy which progresses from concrete attribute identification to abstract class recognition, individuals heavily dependent upon concrete cues would experience difficulty on the classification hierarchy—particularly with those levels dealing with class recognition [Levels 4,5,6]—while those

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1. The six levels are: Level I, Attribute Identification; Level II, Attribute Recognition; Level III, Object Recognition; Level IV, Class Recognition; Level V, Class of Classes Recognition (one class); Level VI, Classes of Classes Recognition (two classes).

individuals not dependent upon concrete cues would be expected to experience little difficulty on the hierarchy and hence achieve the highest levels. If the organization of the Order of Classification and the hierarchical test based on it are valid, subjects' performance would be expected to conform according to their developmental level as defined by Piaget.

Those subjects categorized as concrete operational would be expected to perform poorly on the hierarchical test, achieving the lower levels [Levels 1-3] and experience difficulty with the upper levels [Levels 4-6]. Those subjects categorized as formal operational would be expected to perform successfully on the test, achieving the higher levels [Levels 4-6] with little difficulty. In addition, if the assumption of the hierarchical organization of abstraction is correct, then subjects who fail to achieve a lower level in the hierarchical test should also fail successive higher levels.

METHODOLOGY

Subjects.

The study was based on a sample of 112 students divided into two groups. The subjects were randomly selected from six junior-high schools and seven high schools in urban St. John's, Newfoundland. The junior-high-school subjects, Group I, were randomly selected from 7th and 8th Grade classes and consisted of 52 subjects (ages 12.1 to 17.11 years; mean age = 13.8 years). The high-school group, Group II, were randomly selected from Grades 9 to 11 and consisted of 60 subjects (ages 14.6 to 18.5; mean age = 16.2 years).[2]

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2. Grade 11 is the final year of high school in Newfoundland.

Testing Procedure and Scoring.

Piaget Tasks

A hierarchical classification test and a battery of four Piaget-type tasks were administered individually to each subject. The four Piaget-type tasks were: 1) Conservation of Volume Using Metal Cylinders; 2) Exclusion of Irrelevant Variables (Pendulum); 3) Equilibrium in the Balance; and 4) Proportional Logic and Hypothetical Deductive Reasoning (Stickman). These four tasks were chosen because successful solution of them is indicative of formal operational thought [8]. The administration of each followed criteria and protocols described in the literature [2,11].

Scoring procedures for Tasks 1-3 were also identical to those described elsewhere [2,13]. The scoring procedure for Task 4, Stickman, was modified slightly and is described below:

Weight	Stage	Scoring
1	IIA - Early Concrete	Could not answer or guessed
2	IIB - Concrete Operational	Attempted to reason out the problem using additive-scaling strategies.
3	III - Formal Operational	Proportional Reasoning in stating the correct answer.

A total score for each individual was calculated and used to categorize the subject as either Concrete, Transitional or Formal. The score ranges for each of the three categories were as follows:

Concrete	4 - 9
Transitional	10 - 11
Formal	12 - 14

Classification Hierarchy

The classification hierarchy used in this study consisted of a series of tests representing each level of abstraction in the Order of Classification. To measure all six levels, eight subtests were used (two subtests were used for Level IV and Level V). The subtests consisted of an example box, which contained two concrete examples of the instance to be learned, and the test box, which contained two different concrete examples of the instance taught, plus four distractors. The S's were taught the correct instance with the example box and then were asked to identify these two instances in the test box. Since the contents of the test box were used to assess the subject's ability to acquire the abstraction taught to him, no verbal cues were given. All tests for the six levels of abstraction in the Order of Classification were constructed and presented in this manner, except that the attributes of the sample and test box items become more abstract as the test sequence progressed.

The criterion level of achievement was successful completion of the task within two trials. Upon successful completion of Level I, the subject was assessed at Level II, in the same manner and with the same criteria for success. Successful completion for all tests occurred when the subject identified both instances correctly. Unsuccessful completion of the test occurred when the subject (a) failed to identify either instance correctly, (b) only identified one instance correctly, or (c) identified both instances but also placed one or more incorrect instances in the correct group. The maximum level that a subject could achieve was 6, the highest level in the hierarchy. To reach Level 6, the subject had to pass all eight subtests. If a subject failed to achieve a particular level with two trials, the testing sequence was still continued, however, to the highest level. By testing to the highest level, it was possible to detect whether a subject

could, by some cognitive process that was not predicted in the rational of the study, go to a higher level after failing a lower one. A detailed description of the hierarchical test used in the study has been reported elsewhere [6,7].

RESULTS

Piaget Task Results.

Table I shows the percentage of students according to developmental level. In Group I (Grades 7 and 8) 88.5% of the students scored in the concrete range [4-9] and 11.5% scored in the transitional range [10-11]. No student in Group I scored in the formal range. The percentage of Group II students (Grades 9, 10, 11) scoring concrete, transitional, or formal are respectively 70%, 16.7% and 13.3%. These results are consistent with those reported by others [10].

Average Level Achieved on Hierarchical Test.

Table II displays the average level of abstraction acheived for both groups. As observed in this table, those students in Group I categorized as concrete achieved the lowest level, 3.78. In Group II, those categorized as concrete achieved a slightly higher level, 4.45. Those students categorized as transitional in both Group I and Group II achieved Levels 5.5 and 5.7 respectively. All students in Group II categorized as formal achieved the highest level, Level 6.

Average Cumulative Trials to Criterion.

The six level hierarchical test is composed of eight subtests.

TABLE I

Percentage of Students According to Developmental Level

GROUP I (Grades 7 and 8) N = 52

Concrete (4-9)	88.5%
Transitional (10-11)	11.5%
Formal (12-14)	0%
	100.0%

GROUP II (Grades 9, 10, 11) N = 60

Concrete (4-9)	70.0%
Transitional (10-11)	16.7%
Formal (12-14)	13.3%
	100.0%

TABLE II

Average Level Achieved on Hierarchical Test*

GROUP I (Grade 7, 8) Category	N = 52 Average Level
Concrete (4-9)	3.78
Transitional (10-11)	5.50

GROUP II (Grades 9, 10, 11) Category	N = 60 Average Level
Concrete (4-9)	4.45
Transitional (10-11)	5.70
Formal (12-14)	6.0

*The higest level that could be achieved on the test was Level 6

The minimum number of cumulative trials to reach level 6 is eight (when criterion is achieved in one trial for each of the eight subtests) and the maximum number is 16 (two trials required to reach criterion on each subtest). Since all eight tests were administered to each subject, the average cumulative number of trials taken by each group for all eight test provides evidence as to the amount of difficulty each group was experiencing with the hierarchical test. In Table III, the average cumulative trials to criterion per developmental level per group is set forth. As can be seen in Table III the Group I concrete experienced the greatest difficulty on the test, followed by the Group II concrete students. The formal operation students in Group II experienced little difficulty with the test, scoring 10.09, trials to criterion while the transitional students from both Groups I and II scored slightly higher, 10.96 and 10.20, respectively.

Chi-Square Analysis.

A chi-square analysis of developmental level by hierarchical level for Groups I and II is displayed in Table IV and Table V. In Group I, 32 students out of 46 (70%) categorized as concrete were unable to score higher than Level 3. The remaining 14 students (30%) categorized as concrete in Group I were able to achieve higher levels [Levels 4,5,6]. Those students categorized as transitional in Group I were able to achieve the higher levels in the hierarchy, with 4 S's achieving Level 6 and one each at Level 4 and 5.

In Group II, 18 students (43%) categorized as concrete achieved no higher than Level 3. The remaining 24 students (57%) were capable of achieving the upper levels of the hierarchy. With the exception of one student in the transitional category, all students in Group II categorized as either transitional or formal achieved the highest level, Level 6.

TABLE III

Average Cumulative Trails to Criterion at each Level of Abstraction and for Developmental Level of the Subjects

Level	Test	Group I Concrete	Group II Concrete	Group I Transitional	Group II Transitional	Group II Formal
I	1	1.26	1.11	1.00	1.11	1.00
II	2	2.39	1.20	2.16	1.22	2.00
III	3	3.73	3.27	3.16	3.33	3.00
IV	4	5.25	4.60	4.66	4.44	4.22
	5	7.18	6.50	6.49	6.10	5.99
V	6	9.02	8.04	8.15	7.54	7.21
	7	10.56	9.49	9.31	8.87	8.43
VI	8	12.40	11.39	10.96	10.20	10.09
		n=46	n=42	n=6	n=9	n=9

Group I (Grades 7, 8); N =52

Group II (Grades 9, 10, 11); N =60

TABLE IV

CHI-Square Analysis of Developmental Level
By Hierarchical Level*

GROUP I (Grades 7, 8) N = 52

OBS (f) ROW PCT COL PCT TOT PCT	Hierarchical Level 1	2	3	4	5	6	
Concrete	1.0 2.2 100.0 1.9	3.0 6.5 100.0 5.8	28.0 60.9 100.0 53.8	-	1.0 2.2 50.0 1.9	13.0 28.3 76.5 25.0	46.0 58.5
Transitional	-	-	-	1.0 16.7 100.0 1.9	1.0 16.7 50.0 1.9	4.0 66.7 23.5 7.7	6.0 11.5
	1.0 1.9	3.0 5.8	28.0 53.8	1.0 1.9	2.0 3.8	17.0 32.7	52.0 100.0

$x^2 = 17.13$, df = 5, p = .01

*CHI-square tables IV and V represent an SPSS computer output format.

TABLE V

CHI-Square Analysis of Developmental Level
By Hierarchical Level *

GROUP II (Grades 9, 10, 11) N = 60

OBS (f) ROW PCT COL PCT TOT PCT	Hierarchical Level 3	4	5	6	
Concrete	18.0 42.9 94.7 30.0	1.0 2.4 100.0 1.7	9.0 21.4 100.0 15.0	14.0 33.3 45.2 23.3	42.0 70.0
Transitional	1.0 10.0 5.3 1.7	-	-	9.0 90.0 29.0 15.0	10.0 16.7
Formal	-	-	-	8.0 100.0 25.8 13.3	8.0 13.3
	19.0 31.7	1.0 1.7	9.0 15.0	31.0 5.7	60.0 100.0

$x^2 = 19.15$, df = 6, p = .01

The results for both groups are statistically significant at $p < .01$.

Anomalies.

In dealing with human behavior, inconsistencies in performance were expected to occur within each group. Inconsistencies occurred when subjects failed lower levels and then passed higher levels, or sporadically passed or failed levels all the way up the hierarchy. Widely occurring performance of this sort would necessarily invalidate the hierarchical test; however, in both groups the percentage of subjects demonstrating predictable behaviour on the hierarchical test was 88% and 91% respectively.

DISCUSSION

The results support the assumption that students capable of forming and manipulating symbolic representations of experience (Formal Operations) would experience little difficulty on the hierarchical test. All subjects so categorized achieved the highest level, Level 6, and, insofar as the average cumulative trials to criterion as a measure of difficulty experienced on the hierarchical test, these same subjects also achieved the lowest score, 10.09.

Those subjects categorized as between concrete and formal (Transitional) also experienced little difficulty on the hierarchical test. This is indicated by their average level achieved on the hierarchical test, 5.50 and 5.70, and their average cumulative trials to criterion, 10.96 and 10.20, for Groups I and II respectively. It is worth noting that the transitional group did experience some difficulty with the test and, hence, their performance was not as decisive as their formal counterparts.

The assumption that students dependent upon concrete cues would experience difficulty on the hierarchical test is not as clearly supported. While the Group I concrete students, in general, performed as predicted (70% achieving no higher than Level 3, averaging Level 4 (3.78); the Group II concrete students' performance was more varied. (In this group, 43% achieving no higher than Level 3 and 57% achieving higher, averaging as a Group Level 4 (4.45). Although this variability was not predicted, it cannot be considered unusual. Since this study only attempted a general categorization of individuals according to developmental level, all individuals failing formal operational tasks being defined as concrete, it is possible, as a result of such a gross selection process, for individuals categorized as concrete to still perform successfully on the hierarchical test. Piaget argues that

classification ability is only attained when the child has mastered the inclusion relation (the ability to view subclasses and supra-ordinate class in a state of reversible equilibrium[9]. This ability is attained sometime during concrete operations. If Piaget is correct, it is possible that the individuals categorized here as concrete may have mastered the inclusion relation and hence were able to perform successfully on the hierarchical test. These results would suggest such an interpretation.[4]

It is important to note that while some subjects categorized as concrete were able to achieve the highest level in the hierarchy they were still unable to perform successfully on the formal operational tasks. This suggests that hierarchical classification while demanding abstract reasoning ability may be a less demanding cognitive task and hence precedes the learning of more complex relational problems such as those presented by the formal tasks. This result supports other studies which allude to the priority of classification ability in human learning [8,9].

With respect to formal operation, recent studies in North America have found that the age ranges delineating the developmental levels of Piaget's theory are inappropriate for North American children [1,3,10]. For example, Piaget has claimed that formal operations begin around 11 or 12 years [8]. This suggests that North American children have attained formal operations by the time they have entered junior high school. However, current findings demonstrate that this may be

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4. Since this study was concerned with hierarchical classification and not a detailed examination of classification processes in general, such a conclusion must be speculative. Whether the hierarchical test used here is measuring mastery of the inclusion relation or not, must be left open for a future study. In addition, these results also support other studies cautioning against assuming that students cognitive ability can be meaningfully characterized by such labels as concrete and formal [13,14].

too early, since many high school (15-17 years old and older) students have yet to attain formal operations. The data reported in this study are the first obtained from a relatively remote section of North America and add further support to those studies suggesting the inappropriateness of Piaget's original age ranges for North American children, particularly for formal operations [3,10].

As an exploratory study, these results provide further evidence that the model of abstraction and the test based on that model can be considered a valid indicator of cognitive ability. It also adds additional evidence for an interrelation between Piagetian concepts of mental development and a formal model of abstract thinking, thus enhancing the network of information clustering around Piagetian developmental psychology. Evidence has been obtained to indicate that the ability to organize information in hierarchical arrays is dependent upon the degree to which an individual can form and manipulate representations of experience. Individuals dependent upon concrete cues, moreover, demonstrated less success with this ability. Further support is indicated by the large percentage of subjects who failed lower levels on the test and went on to fail higher levels. It is important to note, however, that the test used here is a mediating mechanism and that a different form of the test, insofar as it has face validity, might yield different results. Nonetheless, this study has yielded strong support for the hierarchical test and the model on which it is based.

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